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(54) **AIR TO AIR ACTIVE REFUELLING SYSTEM AND METHOD FOR GENERATING AERODYNAMIC RADIAL LOADS AT A HOSE-END**

(57) The present invention belongs to the field of air to air refuelling for aircraft, in particular to the field of systems for monitoring and adapting the movement at the end of an air to air refuelling hose of a tanker aircraft. More particular, the inventions provides an improved ac-

tive system for an air to air refuelling operation which intends to counteract the undesirable movements at the end of the hose though generating aerodynamic loads in the end of the hose.

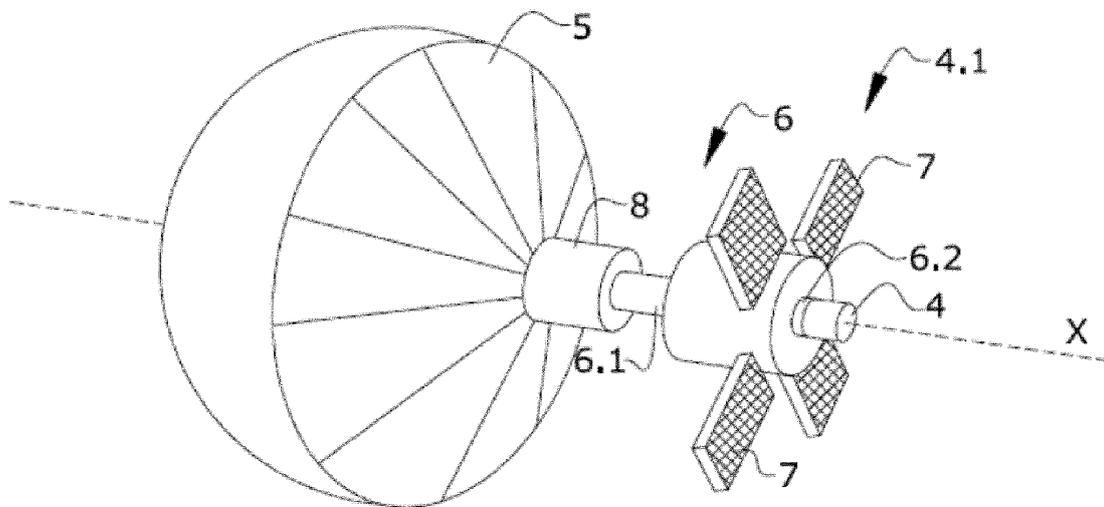


FIG.4

EP 3 842 345 A1

Description

TECHNICAL FIELD OF THE INVENTION

[0001] The present invention belongs to the field of air to air refuelling for aircraft, in particular to the field of systems for monitoring and adapting the movement at the end of an air to air refuelling hose of a tanker aircraft. More particular, the invention provides an improved active system for an air to air refuelling operation which intends to counteract the undesirable movements at the end of the hose through generating aerodynamic loads in the end of the hose.

BACKGROUND OF THE INVENTION

[0002] Current air to air refuelling is a well-known manoeuvre in the field of aircraft where a tanker aircraft operates to provide in-flight fuel to a second aircraft called receiver aircraft. One of the most used operating system nowadays is based on a hose & drogue system. These systems are mainly used in a passive way relying on the skills of receiver aircraft pilot which cause a high ratio of unsuccessful contacts. Those failed contacts can have operational and/or safety consequences.

[0003] In current air to air refuelling methods, First of all, the drogue is stored in the tanker aircraft and the system is turned off while the tanker aircraft pilot stabilizes the aircraft at air to air refuelling altitude. Then, the drogue is still stored in the tanker aircraft and the system is turned on while a second aircraft called receiver aircraft waits for further instructions from the tanker aircraft for initiating the refuelling operation. Next, the drogue is extended from the tanker aircraft and the hose is deployed till reaching a stand-by position while the receiver aircraft is still waiting. Then, the receiver performs an approach to face the drogue with a receiver probe. While the receiver aircraft tries to make contact with the drogue it creates a phenomenon called *Bow Effect* which moves the drogue from its balance position. This specific step of approaching completely relies on receiver aircraft pilot skills and anticipation to the drogue movements. It is well known that this step can be the consequence of a lot of tanker/receiver/drogue damages and results as well as an unsuccessful contact operation. Once the receiver aircraft succeeds to make contact with the drogue, it pushes the drogue with the receiver probe to complete contact between the system of the tanker aircraft and the receiver aircraft. While the receiver aircraft pushes the drogue, a phenomenon called *Whipping* can appear on the contact area which is caused by the impact of the receiver probe transmitted to the hose in wave form. Such as the previous step mentioned, the pushing operation is also considered as a dangerous manoeuvre of the current air to air refuelling operation. Then, the fuel starts to be dispensed from the tanker aircraft but the drogue is still submitted to radial loads transmitted by the receiver aircraft which means that risk of damage is not eliminated until

full disconnection of the receiver aircraft from the drogue. Finally, the receiver aircraft goes backward and starts to disconnect the receiver probe from the drogue. If needed, the operation can be repeated more than once with the same tanker aircraft.

[0004] The actual air to air refuelling methods implicate a list of resulting effects and uncertainties due to manual approach, aerodynamic loads in the components on the contact region and tensions created by this complex flying operation.

[0005] Most of the air to air refuelling methods, above-mentioned, are carried out passively, and very few are actively performed. Some methods are known for incorporating an active control of the hose-end and its position, however, none of these methods have progressed to a valid in-service solution due to drawbacks. Some of these drawbacks present in an active control of the hose are: difficult integration between the air to air refuelling system and the tanker aircraft, low aerodynamic load capability of the system, transmission of torsion loads to the hose of the system, absence of a fixed referenced of the hose-end because of the hose torsion, and ensure the safety of the operation.

[0006] Therefore, the present invention provides an improvement in the active control of the hose-end in order to introduce aerodynamic forces in radial direction and achieve a control capability beneficial to reduce unsuccessful contacts ratio though automatization of the contact operation. Furthermore, the air to air active refuelling system provided by the present invention reduces drogue oscillations, tanker aircraft and/or receiver aircraft damages, increases safety during the refuelling operation and mission reliability.

SUMMARY OF THE INVENTION

[0007] The present invention provides a solution for the aforementioned problems, by an air to air active refuelling hose according to claim 1, a tanker aircraft according to claim 13 and a method for generating aerodynamic radial loads at a hose-end of an air to air active refuelling system according to claim 14. In dependent claims, preferred embodiments of the invention are defined.

[0008] In a first inventive aspect, the present invention provides *an air to air active refuelling system for a tanker aircraft, the system comprising:*

- a hose suitable for driving fuel inside,
- a coupling arranged at a hose-end of the hose and comprising a drogue, the drogue being configured to be coupled to a probe of a receiver aircraft in a refuelling operation,
- a hose-end control unit "HCU" located at the hose-end, the HCU comprising
 - at least three grid fins, each grid fin located on a fin shaft, these grid fins being configured to be

folded or deployed when the system requires, so that when these grid fins are in a deployed state:

- *the plurality of grid fins is further configured to rotate with respect to a longitudinal axis, along which the HCU is arranged, and*
 - *each grid fin adapts their deflection angle by means of the independently rotation of each grid fin around its respective fin shaft;*
- *an inertial measurement unit "IMU" configured to measure the acceleration of the hose-end; and*
- *first sensing means configured to measure the relative position between the first sensing means location and the probe of the receiver aircraft; and*
 - *a processing unit connected to the HCU, the IMU and the first sensing means, this processing unit being configured to process the measurements from the IMU and the first sensing means,*

wherein the HCU of the system, based on the measurements from the IMU and the first sensing means, actuates the deflection angle in each grid fin independently and the rotation of the at least three grid fins in order to provide aerodynamic radial loads at the hose-end.

[0009] The present invention provides in this first inventive aspect a system intended to be installed in a tanker aircraft for providing aerodynamic loads to counteract the undesirable movements at the end of the hose in an air to air refuelling operation between the tanker aircraft and a receiver aircraft. These undesirable movements at the hose-end are external forces or perturbations that could move the drogue from its equilibrium position in the refuelling operation, and particularly in the contact operation. The "contact operation" will be understood as the operation in which the drogue of the present system comes into contact with a receiver probe of a receiver aircraft.

[0010] That is, the present invention provides an improved system with a hose-end with the capability of being controlled in order to provide automatic drogue stabilization as a receiver aircraft approaches to contact.

[0011] The present system is an active system given that the configuration of the hose movement in the refuelling operation is based on the information provided by the HCU system (not from the receiver aircraft) so that the receiver connection based on receiver pilot skills is facilitated. That is, the present system provides an active control of the hose facilitating the contact in the refuelling operation by means of introducing aerodynamic radial loads at the hose-end in a new way compared with the prior art solution.

[0012] The air to air refuelling system is mainly formed by means of a hose and a drogue arranged at one end of the hose. The hose comprises two ends, a first end

intended to be coupled to a probe of the receiver aircraft by means of the drogue and a second end intended to be fixed to the tanker aircraft. Through this hose a fuel supply is provided from the tanker aircraft to the receiver aircraft, that is, from one hose-end to the other hose-end. Throughout this document when reference is made to "hose-end", this will be understood as the free end of the hose through which the coupling with the receiver aircraft is performed. In addition, in case the other end of the hose is referred to, it will be referred to as the hose-end that is fixed to the tanker aircraft. The drogue is comprised in a coupling that is located at the hose-end.

[0013] The present system further comprises a hose-end control unit "HCU" in charge of providing aerodynamic radial loads at the end of the hose by means of at least three fins comprised in this HCU. The HCU is located at the hose-end, in a particular example, between the hose and the coupling, and in another particular example the HCU is located on the coupling. In a particular embodiment, this HCU is configured to be connected to an aircraft control equipment located at the tanker aircraft. In particular, this aircraft control equipment is understood as a controller that is responsible for the operation of the HCU at the hose-end in this particular embodiment.

[0014] The system further comprises a processing unit connected to the HCU and can be installed in the HCU or in the tanker aircraft. In any case, the processing unit processes the information from the HCU and is able to determine autonomously the aerodynamic loads needed at the hose-end or may send this information to an aircraft control equipment of the tanker aircraft for determining the aerodynamic loads needed at the hose-end.

[0015] The HCU comprises a plurality of fins with a grid configuration which is in charge to generate aerodynamic radial loads at the hose-end. Each fin is perforated along its entire length forming a grid configuration. The grid fins are attached to a frame of HCU by means of fin shaft in such a way that these fins can be folded or deployed with respect to the HCU. That is, each grid fin is arranged on a fin shaft. In a folded state, the plurality of grid fins is folded towards the HCU frame. In a deployed state, the plurality of grid fins is deployed outward the HCU frame, that is, away from the HCU.

[0016] The grid fins advantageously are able to be folded in a reduced volume, allowing them to be stored in a tunnel of a rear fairing where the hose and drogue devices (hose, coupling, drogue and HCU) are housed when not in use and the system is installed in a tanker aircraft. That is, the present configuration of grid fins attached to the HCU facilitates the integration of the system in the tanker aircraft.

[0017] Advantageously, the grid configuration of the fins provides a reduced hinge movement and has a better integration performance since can be easily folded and deployed. In addition, this grid configuration has higher drag than conventional fins of the state of the art (without a grid configuration). This grid configuration is an advan-

tage in the present system since the drag force is useful for controlling the axial forces at contact operation between the drogue of the tanker aircraft and the receiver aircraft. That is, the shape of the fins and their ability to be folded or deployed allow the system increases its aerodynamic load capability compared to the prior art solution by means of generating the necessary loads to counteract adverse movements at the hose-end.

[0018] When the grid fins are in a deployed state, this plurality of grid fins is also configured to rotate around a longitudinal axis and independently adapt their deflection angle. It will be understood that the grid fins rotate all at once with respect to a longitudinal axis along which the HCU is arranged. In particular, this longitudinal axis will correspond to the longitudinal direction that the hose-end follows where the HCU is located. Therefore, it will be understood that the grid fins can rotate around the hose at the hose-end. Furthermore, the deflection angle is configured independently for each grid fin by rotating each grid fin around its respective fin shaft. Particularly, the grid fins are configured to be actuated by the HCU under any external force to change the deflection angle in each grid fin independently. This change in the deflection angle of a grid fin will be understood as the own rotation of the grid fin on itself.

[0019] Therefore, the HCU provides aerodynamic radial loads at the hose-end by means of adjusting the deflection angle of each grid fin appropriately and rotating the plurality of grid fins when these grid fins are in the deployed state. The aerodynamic loads provided by the present system at the hose-end are radial loads given that the plurality of grid fins rotates all together with respect to a rotation axis so that loads acting perpendicular to the rotation axis are generated.

[0020] The present system is an improved air to air refuelling system given that the HCU has an active control of the radial generated aerodynamic force at the hose-end in order to adapt his hose-end to the external perturbations. These radial forces generated by the HCU are transmitted to the hose, the coupling and the drogue.

[0021] The HCU further comprises an inertial measurement unit "IMU" located at the HCU frame and intended to measure the movement of the hose-end, specifically to measure the acceleration at one point of the hose-end. That is, the IMU measures the acceleration of the HCU in a refuelling operation. Thus, this IMU advantageously allows the system to monitor in real time, the movement of the HCU in the air to air refuelling operation.

[0022] The present system further comprises first sensing means for measuring the relative position between the localization of said first sensing means in the system and the probe of receiver aircraft. That is, the first sensing means are able to detect the relative position between their location and the probe of the receiver aircraft, having complete information about the spatial location of the tanker, the hose-end and the probe of the receiver aircraft.

[0023] In a particular embodiment, *the first sensing*

means are located on the hose-end of the tanker aircraft and are configured to measure the relative position between the hose-end and the probe of the receiver aircraft.

Particularly, the first sensing means are able to detect the relative position of the receiver probe with respect to the drogue arranged on the hose-end. In another particular embodiment, *the first sensing means are configured to be located on the tanker aircraft and to measure the relative position between the tanker aircraft and the probe of the receiver.* In this embodiment, when the system is in an operative mode installed in the tanker aircraft, the first sensing means are located in this tanker aircraft.

[0024] In a more particular embodiment, the first sensing means are ultrasound or infrared sensors, or visible, infrared and image processing cameras, or TOF (*time-of-flight*) camera, or any combination of the above.

[0025] Both IMU and first sensing means are connected to the processing unit so that the measurements from the IMU and first sensing means are used in a closed control loop in the processing unit to command, by the HCU, the fins to counteract the undesired hose movements.

[0026] That is, the measurements performed by the IMU and first sensing means are processed by the processing unit for determining the aerodynamic loads needed at the hose-end. Furthermore, the connecting between the processing unit and the HCU monitors the status of the HCU thus allowing internal failure detection.

[0027] The IMU and first sensing means specifically allows the system to have knowledge of the attitude of the HCU during the active mode (refuelling operation) in order to perform an active control of the system, as well as also allows the aircraft control equipment (when the system is connected to the tanker aircraft) to have information from both the IMU and first sensing means.

[0028] Based on the IMU and sensing means measurements and the conditions of the refuelling operations, the system by means of the processing unit determines in an operative mode (when the system is connected to the tanker aircraft) the aerodynamic loads that are necessary to counteract the undesirable movements at the hose-end in order to facilitate the contact operation between the tanker aircraft and the receiver aircraft. Particularly, the processing unit will be understood as a device comprising a controller in charge of control the HCU and send commands to the HCU.

[0029] In other embodiment, an aircraft control equipment from the tanker aircraft determines in an operative mode (when the system is connected to the aircraft control equipment in a tanker aircraft) the aerodynamic loads that are necessary to counteract the undesirable movements at the hose-end in order to facilitate the contact operation.

[0030] Once the needed aerodynamic loads are determined, the system is configured to command the HCU (either by the processing unit or the aircraft control equipment) to adapt the deflection angle of each grid fin independently and to rotate the plurality of grid fins. The ro-

tation of the plurality of grid fins, already with their deflection angle adapted, provides the desired aerodynamic radial loads at the hose-end.

[0031] The present system advantageously increases the successfully contacts ratio by stabilizing the hose-end compared to the prior art systems. In addition to this benefit, the system is useful to guide the coupling with the drogue to the receiver aircraft, particularly to a receiver probe of this receiver aircraft, achieving an autonomous/assisted contact easing the manoeuvre from the receiver aircraft.

[0032] Moreover, the present system is able to keep a fixed reference of the hose-end thanks to the relative position of the hose-end obtained by means of a closed control loop. That is, this closed control loop obtains the relative position from the first sensing means and acts independently in the deflection angle of each grid fin to keep the required roll at the hose-end in the refuelling operation.

[0033] Therefore, the present system is able to monitor the provision of loads at the hose-end according to relative position between the drogue and the receiver probe and the acceleration on the hose-end. When the system detects by means of the processing unit that there is no need to provide loads at the hose-end, the system stops this load provision by the HCU.

[0034] In a particular embodiment, *the HCU comprises:*

- *a fix frame arranged along the longitudinal axis and mechanically connecting the hose to the coupling, and*
- *a rotary frame rotationally connected to the fix frame and comprising the plurality of fin shafts on which the grid fins are fixed, this rotary frame being configured to rotate around the longitudinal axis thus allowing the free rotation of the plurality of grid fins.*

[0035] The HCU has the functions of providing a mechanical connection between the hose and the coupling and the loads transition, and generating aerodynamic loads to stabilize the drogue. Particularly, the HCU is formed by a fix frame and a rotary frame.

[0036] The fix frame of the HCU is mechanically connected to the hose and the coupling at the hose-end. This fix frame is the link that transmits axial and torsion loads between complete assemblies at the hose-end. The link between the hose and the coupling follows a longitudinal axis. Likewise, the rotary frame of the HCU is installed over the fix frame and rotationally connected to this fix frame so that his rotary frame can rotates around the longitudinal axis.

[0037] There are also a plurality of fin shafts attached to the rotary frame on which the grid fins are installed. In this way, when the rotary frame rotates the plurality of grid fins also rotates. This rotary frame advantageously allows that the torsion loads transmitted from the HCU to the hose be less than the maximum torsion admissible

by hose qualification. Thus, the rotary frame is the support part of the HCU where all the actuation system is installed.

[0038] Furthermore, the fix frame of the HCU comprises mechanical interfaces which compatibilities the attachment of the HCU between the hose and the coupling.

[0039] Advantageously, the particular configuration of HCU comprising a fix frame and a rotary frame allows the grid fins to be properly positioned without transmitting torsion loads to the hose.

[0040] In a particular embodiment, *the rotary frame is installed over the fix frame of the HCU by means of bearings thus allowing the free rotation of the rotary frame around the longitudinal axis.*

[0041] Bearings are arranged around the fix frame of the HCU to support the rotary frame of the HCU and to allow this rotary frame to rotate around the longitudinal axis. Specifically, these bearing transmit providing connections from the fix frame to the rotary frame of the HCU so that it allows the rotation between both fix and rotary frames of the HCU.

[0042] Advantageously, this configuration of HCU allows the rotary frame rotates independently from the hose of the present system.

[0043] In a particular embodiment, *the system comprises four grid fins and their respective fin shafts, wherein the fin shafts are separated at 90° from each other with respect to the longitudinal axis.* This particular configuration of the position of the grid fins advantageously avoids the hose shadow and therefore prevents to perturb the grid fins performances.

[0044] In a more particular embodiment, according to a plane transverse to the longitudinal direction, two of the grid fins are at 45° with respect to a vertical axis and the other two grid fins are at 45° with respect to a horizontal axis, both vertical and horizontal axes contained in the transverse plane and perpendicular to each other. The "transverse plane" will be understood as a vertical plane that is perpendicular to the longitudinal axis already defined. In this vertical plane there will be defined a vertical axis and a horizontal axis. Both vertical and horizontal axis are perpendicular between them and also perpendicular to the longitudinal direction.

[0045] In a particular embodiment, *the HCU further comprises for each grid fin an actuator for providing the deflection of the grid fin with respect to their fin shaft according to the system requires.* That is, these actuators are in charge to provide the movement for the deflection of the grid fins adapting independently the deflection angle of each grid fin. The fact that there is one actuator for each grid fin allows, advantageously, independent control of each grid fin. In a particular embodiment, the actuators are configured to transform a lineal movement into a rotational movement for the deflection of the grid fins.

[0046] In a more particular embodiment, the actuators are electromechanical actuators.

[0047] In a particular embodiment, *each fin shaft is*

supported by two fin shaft bearings and mechanically connected to the actuator.

[0048] In another particular embodiment, each actuator comprises second sensing means for sensing the deflection angle of the corresponding grid fin. These sensing means are configured to give feedback information to the processing unit or to an aircraft control equipment of the tanker aircraft in an operative mode about the deflection angle of each grid fin in real time. In a more particular embodiment, the second sensing means are a sensor installed in each fin. Depending on the sense of deflection of the grid fins, the force in the hose-end will go to one way or to another according to the system requires.

[0049] In a particular embodiment, the HCU further comprises a folding mechanism configured for folding or deploying the plurality of grid fins with respect to the HCU.

In a more particular embodiment, the folding mechanism comprises a retraction mechanism common to the plurality of grid fins. In a particular embodiment, this retraction mechanism may comprise a solenoid through which the retraction of the plurality of grid fins is performed guiding the fins towards the HCU frame. Particularly, this retraction mechanism is common to all the grid fins, thus, the folding and deployment of the fins is performed at the same time. In another particular embodiment, the retraction mechanism is configured to fold or deploy each grid fin independently. In any of the embodiments mentioned for the retraction mechanism, this is an electromechanical actuation system.

[0050] In a more particular embodiment, the folding mechanism is independent of the deflection actuation on the grid fins. This configuration allows the system to control independently the actuation of the deployment and retraction of fins of the actuation of the deflection of each grid fin as well as the rotation of the plurality of grid fins.

[0051] Moreover, the folding mechanism ensures the capability of the fins to be folded to deal with any system failure as hose unexpected oscillations and hose extension/retraction. In this sense, when the system energized or power supply failure occurs, the system is configured to ensure the fins to be folded. In a particular embodiment, the folding mechanism is performed through a concentric mechanism connected to each fin through a lever that permits the movement of the fin. In this example, the actuation is performed through a linear actuator directly aligned to the fin shaft. In another example, the actuation is performed through a slope mechanism that permits folding the grid fins at the same time.

[0052] The present system further comprises power supplying means configured to supply power at least to the components of the system such as the HCU, the processing unit and the first sensing means. The power supplying means may be batteries or located on the system. Furthermore, the communication between the components of the system, such as between the HCU and the first sensing means with the processing unit is wireless.

[0053] In a second inventive aspect, the present invention provides a tanker aircraft comprising an air to air active refuelling system according to the first inventive aspect.

5 **[0054]** The air to air active refuelling system is arranged at the tanker aircraft so that the hose of this system is connected to the tanker aircraft at a hose-end opposite to the hose-end where the coupling with the drogue and the HCU are located. The air to air refuelling system is intended to supply fuel from the tanker aircraft to a receiver aircraft by coupling the hose to a receiver probe of the receiver aircraft through the drogue of the present system.

10 **[0055]** In a particular embodiment, the tanker aircraft comprises an aircraft control equipment connected to the air to air refuelling system and its components such as the HCU, the processing unit and the first sensing means. Specifically in a particular embodiment, the aircraft control equipment is configured to determine the aerodynamic radial loads needed at the hose-end of the system based on the information from the IMU located at the HCU and the first sensing means and processed by the processing unit.

15 **[0056]** The system can be autonomous in such a way that the processing unit is in charge of controlling the operation of the system even when the system is in an operating mode installed on the tanker aircraft. In another particular embodiment, when the system is in an operative mode installed in the tanker aircraft, the operation of this system is controlled by an aircraft control equipment of the tanker aircraft. In this embodiment, the communication between the tanker aircraft and the components of the system is wireless.

20 **[0057]** The aircraft control equipment is formed at least by a controller and an human machine interface "HMI" both connected between them and also suitable to be connected to the air to air active refuelling system. The HMI interacts with the present system to monitor and record the information measured by the system. In addition, the controller is responsible of running the Flight Control Laws and conditioning the data information received and sent from and to the HMI and HCU, first sensing means and processing unit of the system. The mentioned Flight Control Laws are in charge of defining the flight control laws of the air to air refuelling system taken into account all the functionalities of the present system. Therefore, the air to air refuelling system has an active control of the radial generated aerodynamic force at the hose-end in order to adapt it to the external perturbations.

25 **[0058]** In a third inventive aspect, the present invention provides a method for generating aerodynamic radial loads at a hose-end of an air to air active refuelling system according to first inventive aspect, the method comprising the following steps:

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- a) configuring the deflection angle of each grid fin located at the HCU, and
 - b) rotating the plurality of fins by means of the actu-

ation of the HCU,

wherein both the configuration of the deflection angles and the rotation of the plurality of the grid fins are based on measurements processed by the processing unit of the system.

[0059] In a particular embodiment, the method further comprising measuring the acceleration of the hose-end by means of at least the IMU located at the HCU and measuring the relative position between the probe of the receiver aircraft and the drogue of the tanker aircraft by means of the first sensing means to inform the processing unit about the movement conditions of the hose-end in order to determine the aerodynamic radial loads needed at the hose-end.

[0060] All the features described in this specification (including the claims, description and drawings) and/or all the steps of the described method can be combined in any combination, with the exception of combinations of such mutually exclusive features and/or steps.

DESCRIPTION OF THE DRAWINGS

[0061] These and other characteristics and advantages of the invention will become clearly understood in view of the detailed description of the invention which becomes apparent from a preferred embodiment of the invention, given just as an example and not being limited thereto, with reference to the drawings.

- Figure 1 This figure shows a schematic side view of an air to air active refuelling system of a tanker aircraft approaching to a receiver aircraft according to an embodiment of the present invention.
- Figure 2 This figure shows a schematic upper view of the embodiment shown in Figure 1.
- Figure 3 This figure shows a schematic side view of a hose of an air to air active refuelling system according to an embodiment of the present invention.
- Figure 4 This figure shows a schematic perspective view of a hose-end of an air to air active refuelling system according to an embodiment of the present invention.
- Figure 5 This figure shows a schematic side view of the hose-end of an air to air active refuelling system according to an embodiment of the present invention.
- Figure 6 This figure shows a schematic view of an HCU with four grid fins of an air to air active refuelling system according to an embodiment of the present invention.
- Figure 7 This figure shows an architecture model of an air to air active refuelling system according to an embodiment of the present invention.

DETAILED DESCRIPTION OF THE INVENTION

[0062] Figures 1 and 2 show a side and an upper view respectively of an air to air active refuelling system (1) in a refuelling operation between a tanker aircraft (2) and a receiver aircraft (3). In particular, these figures show when the hose (4) of the air to air active refuelling system (1) is in an extended position out of a tanker aircraft (2) and the receiver aircraft is approaching to this hose (4) of the refuelling system (1). The air to air active refuelling system (1) comprises a hose (4) for driving fuel from a tanker aircraft (2) to a receiver aircraft (3) in a refuelling operation. Said hose (4) presents a drogue (5) located at a hose-end (4.1) suitable for being coupled with a probe (13) of the receiver aircraft (3). The hose (4) also comprises another end (4.2) opposite to the already mentioned hose-end (4.1) where the hose (4) is fixed to the tanker aircraft (2). In a refuelling operation, the refuelling system (1) installed on the tanker aircraft (2) extends the hose (4) in order to couple the drogue (5) of the hose-end (4.1) to the probe (13) of the receiver aircraft (3) that is flying closer to the tanker aircraft (2) for allowing the approaching of the drogue (5) towards the probe (13). Once the coupling is achieved, then the fuel starts being driven through the hose (4) from the tanker aircraft (2) towards the receiver aircraft (3).

[0063] Figure 3 shows a schematic side view of a portion of a hose (4) of an air to air active refuelling system (1). The hose (4) comprising a hose-end (4.1) suitable for coupling the air to air active refuelling system (1) to a probe (13) of the receiver aircraft (3) (as shown in figures 1 and 2) by monitoring and generating aerodynamic radial loads at the hose-end (4.1) in order to adapt the movement at the end of the hose (4) while approaching the probe (13) of the receiver aircraft (3). The hose-end (4.1) comprises a drogue (5) and a coupling (8), the drogue (5) is arranged through the coupling (8) and is the component of the refuelling system (1) that is directly coupled to a probe (13) of a receiver aircraft (3) in refuelling operations (as in figures 1 and 2).

[0064] According to figure 3, the hose-end (4.1) also comprises a Hose Control Unit "HCU" (6) for providing aerodynamic radial loads at the end of the hose (4) in order to adapt the flight conditions of the refuelling system (1) in a refuelling operation. Particularly, the HCU (6) is located between the hose (4) and the coupling (8). Said HCU (6) shows three grid fins (7) in a deployed state. These grid fins (7) can be folded or deployed following the need of adapting the movement of the hose-end (4.1) in a refuelling operation. The grid fins (7) are deployed from the HCU (6) towards outside this HCU (6).

[0065] Figures 4 and 5 show particular examples of an air to air active refuelling system (1). Particularly, figure 4 shows a perspective view of a hose-end (4.1) of the refuelling system (1) in detail and figure 5 shows a side view of another hose-end (4.1) in detail of a refuelling system (1).

[0066] Both refuelling systems (1) of figure 4 and 5

comprise a HCU (6) located at the hose-end (4.1) and comprising a fix frame (6.1) and a rotary frame (6.2).

[0067] The fix frame (6.1) is arranged along a longitudinal axis (X) around the hose (4) at the hose-end (4.1) and the rotary frame (6.2) is rotationally connected to the fix frame (6.1). Said rotary frame (6.2) is configured to rotate around the same longitudinal axis (X) and provide adaptation to in-flight conditions. In figure 4, the HCU (6) shows four grid fins (7) located on the rotary frame (6.2) and in a deployed state. Figure 5 shows a rotary frame (6.2) with three grid fins (7) in a deployed state and fin shafts (10) on which one grid fin (7) is respectively fixed on each fin shaft (10). Specifically, the rotation of the rotary frame (6.2) around the longitudinal axis (X) allows the free rotation of the plurality of grid fins (7) given that the grid fins (7) are fixed to the rotary frame and their respective fin shafts (10) (according to figure 5) are also mounted on said rotary frame (6.2).

[0068] Both figures 4 and 5 further shows a coupling (8) mechanically connected to the hose (4) through the fix frame (6.1) along the longitudinal axis (X). Said coupling (8) is responsible for forwarding the hose (4) to the drogue (5) and ensure the fuel arrival at a drogue (5) also located at the hose-end (4.1) of the refuelling system (1). Said drogue (5) is arranged for connecting the hose-end (4.1) to the probe (13) of a receiver aircraft (3) (shown in figures 1 and 2) in order to confer autonomy and assistance to the receiver aircraft (3) for the approach manoeuvre in a refuelling operation. Particularly, during the contact coupling is able to support axial and radial loads transmitted by the receiver aircraft (3). The contact will be understood as the time in which the drogue (5) of the tanker aircraft (2) comes in contact with the probe (13) of the receiver aircraft (3) (after the moment shown in figures 1 and 2). Therefore, during the contact in a refuelling operation the HCU (6) performs an active control of the axial forces transmitted between the receiver probe (13) and the coupling (8) by generating additional drag force. This additional drag force (aerodynamic radial loads) is provided by the actuation of a deflection angle (α) (shown in figure 6) in each grid fin (7) independently and the rotation of these grid fins (7). Thus, these aerodynamic radial loads at the hose-end (4.1) help to keep the force balance in contact between the tanker aircraft (2) and the receiver aircraft (3), in addition to drogue tension control and coupling latching forces, in a refuelling operation.

[0069] As it can be observed in figure 5, the rotary frame (6.2) comprises gaps (6.2.1) which are suitable for housing the grid fins (7) inside said rotary frame (6.2) when these grid fins (7) are in a folded state.

[0070] Figure 6 shows a schematic view of an example of a rotary frame (6.2) of an HCU (6), this view corresponding to a cross-sectional view to longitudinal axis (X) or the hose (4) of an air to air active refuelling system (1). Particularly, it is shown four grid fins (7) in a deployed state and mounted on the rotary frame (6.2) of the HCU (6). Each grid fin (7) is respectively mechanically con-

nected to this rotatory frame (6.2) by a fin shaft (10). In particular, the fin shafts (10) are separated by 90° from each other respecting the longitudinal axis (X).

[0071] Each grid fin (7) can be actioned by an actuator (not shown in figures) responsible for the deflection of each grid fin (7) independently of the others and with respect to their fin shaft (10) based on the processed information and required adaptation to in-flight conditions. The fin shaft (10) provides to each grid fin (7) the independent rotation that facilitate the adaptation of the desired aerodynamic radial loads at the hose-end (4.1) and ensure the connection of the drogue (5) with the probe (13) of the receiver aircraft (3) in a refuelling operation. Particularly, the independent rotation of each grid fin (7) corresponds to adapting the deflection angle (α) of these grid fins (7).

[0072] Figure 7 shows an architecture model of some of the components that collaborate in the provision of aerodynamic radial load at the hose-end (4.1) of an air to air active refuelling system (1). This refuelling system (1) comprises at least an HCU (6) comprising a plurality of grid fins (7) for generating radial loads at the hose-end (4.1) by deploying the plurality of grid fins (7) and actuating on their deflection angle (α) and their rotation around a longitudinal axis (X) in order to adapt to the in-flight conditions. The HCU (6) further comprises and IMU (9) for measuring the acceleration at the hose-end (4.1). The refuelling system (1) also comprises first sensing means (12) that can be located on the hose-end (4.1) or on the tanker aircraft (2) when the refuelling system (1) in operative mode is installed on said tanker aircraft (2). The first sensing means (12) measures the relative position between the hose-end (4.1) and a receiver aircraft (3) or between the tanker aircraft (2) and the receiver aircraft (3) respectively. Additionally, the refuelling system (1) comprises a processing unit (11) in data connection with the HCU (6) and the first sensing means (12). This processing unit (11) processes the measurements from the IMU (9) and the first sensing means (12), and according to the processed information about the measurements, the processing unit (11) is able to send comments to the HCU (6) for generating the aerodynamic radial loads predefined according to the refuelling system (1) needed in a refuelling operation. The processing unit (11) can be located on the hose-end (4.1) or on a tanker aircraft (2) when the refuelling system (1), in an operative mode, is installed on the tanker aircraft (2).

[0073] The present invention further provides a method for generating aerodynamic radial loads at a hose-end (4.1) (shown in figures 1-6) of an air to air active refuelling system (1) and comprises at least the following steps:

- a) configuring the deflection angle (α) of each grid fin (7) located at the HCU (6), and
- b) rotating the plurality of fins (7) by means of the actuation of the HCU (6),

wherein both the configuration of the deflection angles (α) and the rotation of the plurality of the grid fins (7) are based on measurements processed by the processing unit (11) of the system (1).

[0074] In a refuelling operation, the IMU (9) located on the HCU (6) measures a linear acceleration and angular acceleration at one point of the hose-end (4.1) and send (step c) these measurements to the processing unit (11). In addition, the first sensing means (12) located, for example, on the hose-end (4.1) measure the relative position between the probe (13) of a receiver aircraft (3) and the location of the first sensing means (12) on the hose-end (4.1) of the tanker aircraft (2), and this relative position measurement is also sent (step d) to the processing unit (11). Both steps c) and d) are carried out before the mentioned steps a) and b).

[0075] Once the processing unit (11) received information at least from the IMU (9) and the first sensing means (12), the processing unit (11) processes this information and is able to determine the aerodynamic radial loads needed at the hose-end (4.1). Therefore, according to this predetermined needed, the processing unit (11) commands the HCU (6) to actuate, according to step a), the deflection angle (α) of each grid fin (7) and, according to step b), the rotation of all the grid fins (7) by means of the rotation of the rotatory frame (6.2) of this HCU (6). The processing unit (11) is further able to process the information coming from the IMU (9) and first sensing means (12) and to determine the deflection angle (α) configuration for each grid fin (7) and the velocity of rotation of the rotary frame (6.2) of the HCU (6) for generating the aerodynamic radial load needed at the hose-end (4.1) in the approach to the coupling between the drogue (5) of the tanker aircraft (2) and the probe (13) of the receiver aircraft (3).

[0076] The processing unit (11) is also able to provide folding/deploying actuation of said plurality of grid fins (7) by means of a folding mechanism (not shown in figures) located on the HCU (6). The deploying actuation is performed prior to configure the deflection angle (α) of each grid fin (7) and also prior to rotate these grid fins (7). However, the folding actuation is performed after the generation of aerodynamic radial loads by the actuation of the HCU (6).

[0077] Moreover, the processing unit (11) can be connected to an aircraft control equipment, such as a controller located on the aircraft, so that this control equipment determines the aerodynamic radial loads needed at the hose-end (4.1) instead of the processing unit (11) and sends to the HCU (6) instructions to configure the deflection angle (α) of each grid fin (7) and to rotate these grid fins (7).

Claims

1. Air to air active refuelling system (1) for a tanker aircraft (2), the system (1) comprising:

- a hose (4) suitable for driving fuel inside,
- a coupling (8) arranged at a hose-end (4.1) of the hose (4) and comprising a drogue (5), the drogue (5) being configured to be coupled to a probe (13) of a receiver aircraft (3) in a refuelling operation,

- a hose-end control unit "HCU" (6) located at the hose-end (4.1), the HCU (6) comprising

- at least three grid fins (7), each grid fin (7) located on a fin shaft (10), these grid fins (7) being configured to be folded or deployed when the system (1) requires, so that when these grid fins (7) are in a deployed state:

- the plurality of grid fins (7) is further configured to rotate with respect to a longitudinal axis (X), along which the HCU (6) is arranged, and

- each grid fin (7) adapts their deflection angle (α) by means of the independently rotation of each grid fin (7) around its respective fin shaft (10);

- an inertial measurement unit "IMU" (9) configured to measure the acceleration of the hose-end (4.1);

- first sensing means (12) configured to measure the relative position between the first sensing means (12) location and the probe (13) of the receiver aircraft (3); and

- a processing unit (11) connected to the HCU (6), the IMU (9) and the first sensing means (12), this processing unit (11) being configured to process the measurements from the IMU (9) and the first sensing means (12);

wherein the HCU (6) of the system (1), based on the measurements from the IMU (9) and the first sensing means (12), actuates the deflection angle (α) in each grid fin (7) independently and the rotation of the at least three grid fins (7) in order to provide aerodynamic radial loads at the hose-end (4.1).

2. Air to air active refuelling system (1) according to claim 1, wherein the HCU (6) comprises:

- a fix frame (6.1) arranged along the longitudinal axis (X) and mechanically connecting the hose (4) to the coupling (8), and

- a rotary frame (6.2) rotationally connected to the fix frame (6.1) and comprising the plurality of fin shafts (10) on which the grid fins (7) are fixed, this rotary frame (6.2) being configured to rotate around the longitudinal axis (X) thus allowing the free rotation of the plurality of grid fins

- (7).
3. Air to air active refuelling system (1) according to claim 2, wherein the rotary frame (6.2) is installed over the fix frame (6.1) of the HCU (6) by means of bearings thus allowing the free rotation of the rotary frame (6.2) around the longitudinal axis (X). 5
 4. Air to air active refuelling system (1) according to any of previous claims comprising four grid fins (7) and their respective fin shafts (10), wherein the fin shafts (10) are separated from each other 90° with respect to the longitudinal axis (X). 10
 5. Air to air active refuelling system (1) according to any of previous claims, wherein the HCU (6) further comprises for each grid fin (7) an actuator for providing the deflection of the grid fin (7) with respect to their fin shaft (10) according to the system (1) requires. 15
 6. Air to air active refuelling system (1) according to any of previous claims, wherein each fin shaft (10) is supported by two fin shaft bearings (6.5) and mechanically connected to the actuator. 20
 7. Air to air active refuelling system (1) according to any of claims 5 or 6, wherein each actuator comprises second sensing means for sensing the deflection angle (α) of the corresponding grid fin (7). 25
 8. Air to air active refuelling system (1) according to any of previous claims, wherein the HCU (6) further comprises a folding mechanism configured for folding or deploying the plurality of grid fins (7) with respect to the HCU (6). 30
 9. Air to air active refuelling system (1) according to claim 8, wherein the folding mechanism comprises a retraction mechanism common to the plurality of grid fins (7). 35
 10. Air to air active refuelling system (1) according to any of claims 8-9, wherein the folding mechanism is independent of the deflection actuation on the grid fins (7). 40
 11. Air to air active refuelling system (1) according to any of previous claims, wherein the first sensing means (12) are located at the hose-end (4.1) and are configured to measure the relative position between the hose-end (4.1) and the probe (13) of the receiver aircraft (3). 45
 12. Air to air active refuelling system (1) according to any of claims 1-10, wherein the first sensing means (12) are configured to be located on the tanker aircraft (2) and to measure the relative position between the tanker aircraft (2) and the probe (13) of the receiver aircraft (3). 50
 13. Tanker aircraft (2) comprising an air to air active refuelling system (1) according to any of the previous claims. 55
 14. Method for generating aerodynamic radial loads at a hose-end (4.1) of an air to air active refuelling system (1) according to any of claims 1-12, the method comprising the following steps:
 - a) configuring the deflection angle (α) of each grid fin (7) located at the HCU (6), and
 - b) rotating the plurality of fins (7) by means of the actuation of the HCU (6),
 wherein both the configuration of the deflection angles (α) and the rotation of the plurality of the grid fins (7) are based on measurements processed by the processing unit (11) of the refuelling system (1).
 15. Method according to claim 14, further comprising measuring the acceleration of the hose-end (4.1) by means of at least the IMU (9) located at the HCU (6) and the measurements of the relative position between the probe (13) of the receiver aircraft (3) and the location of the first sensing means (12) by means of the first sensing means (12) to inform the processing unit (11) about the movement conditions of the hose-end (4.1) in order to determine the aerodynamic radial loads needed at the hose-end (4.1).

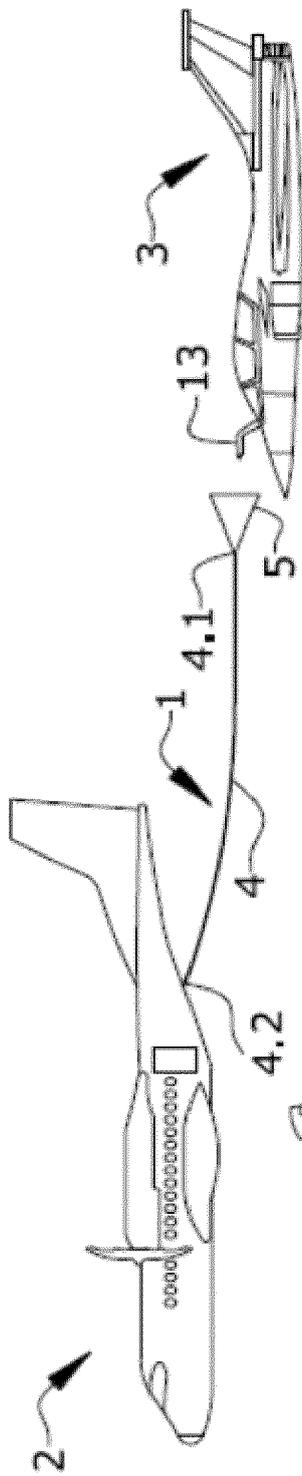


FIG.1

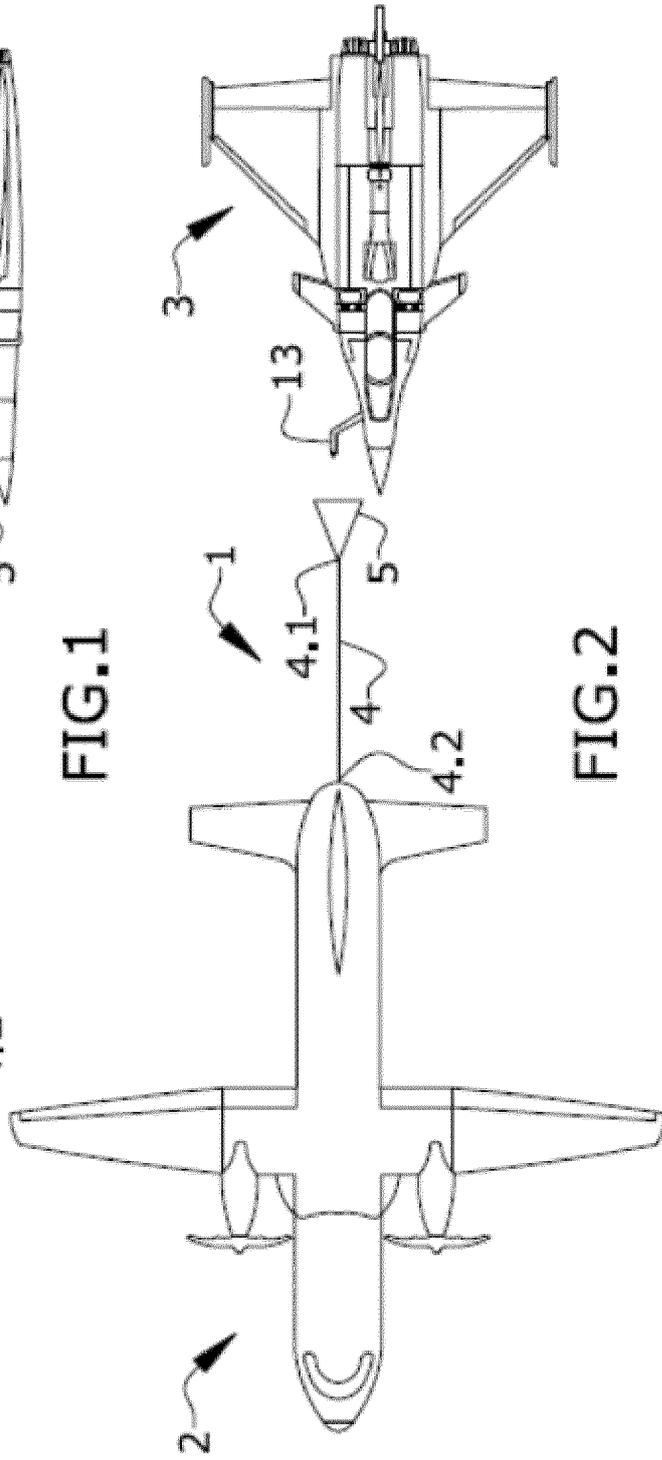


FIG.2

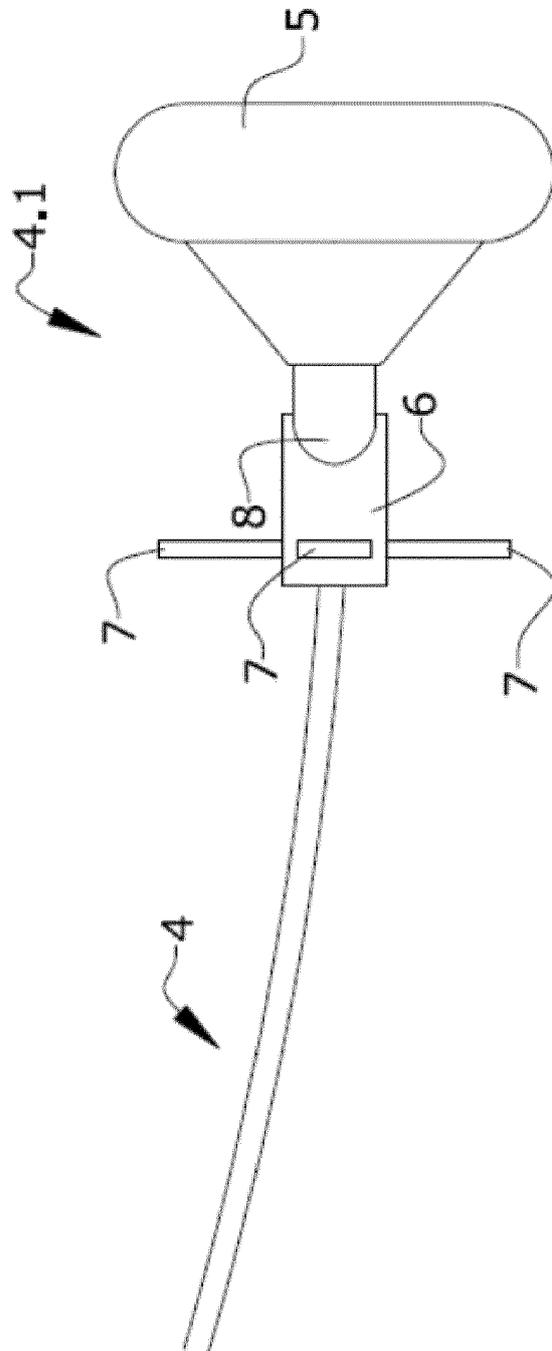


FIG.3

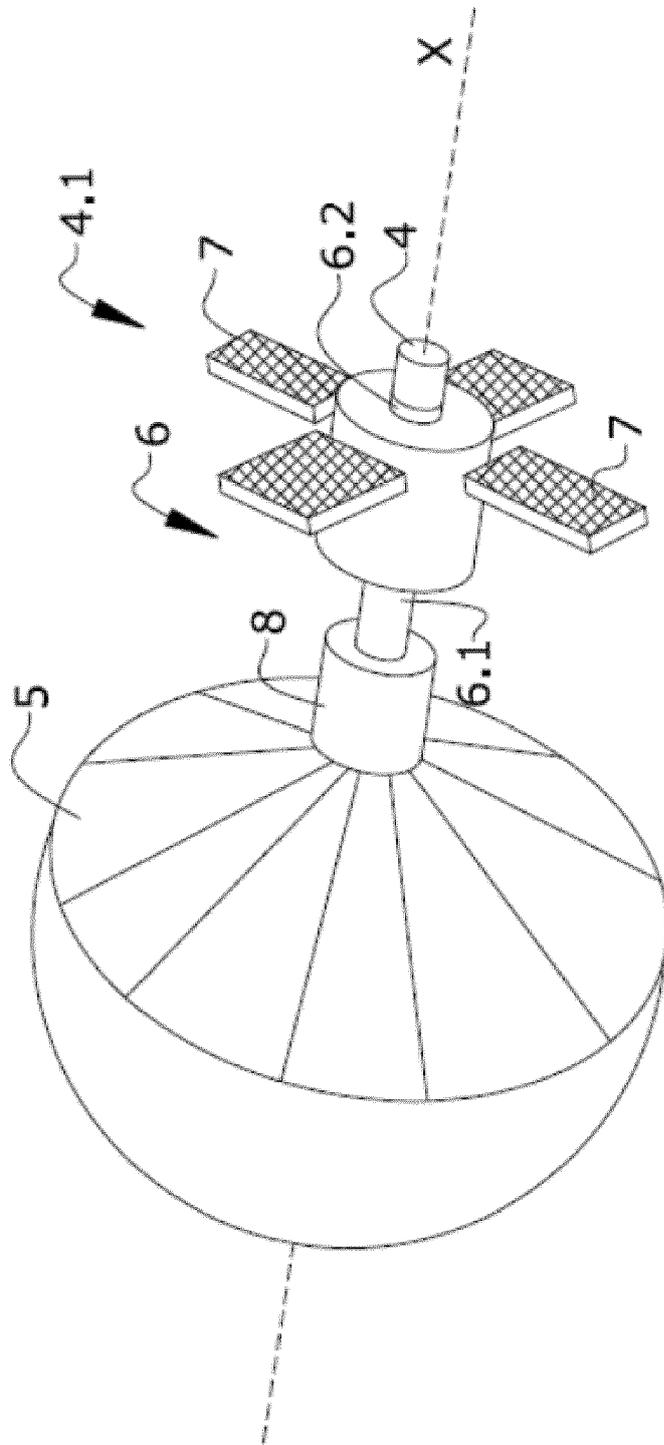


FIG.4

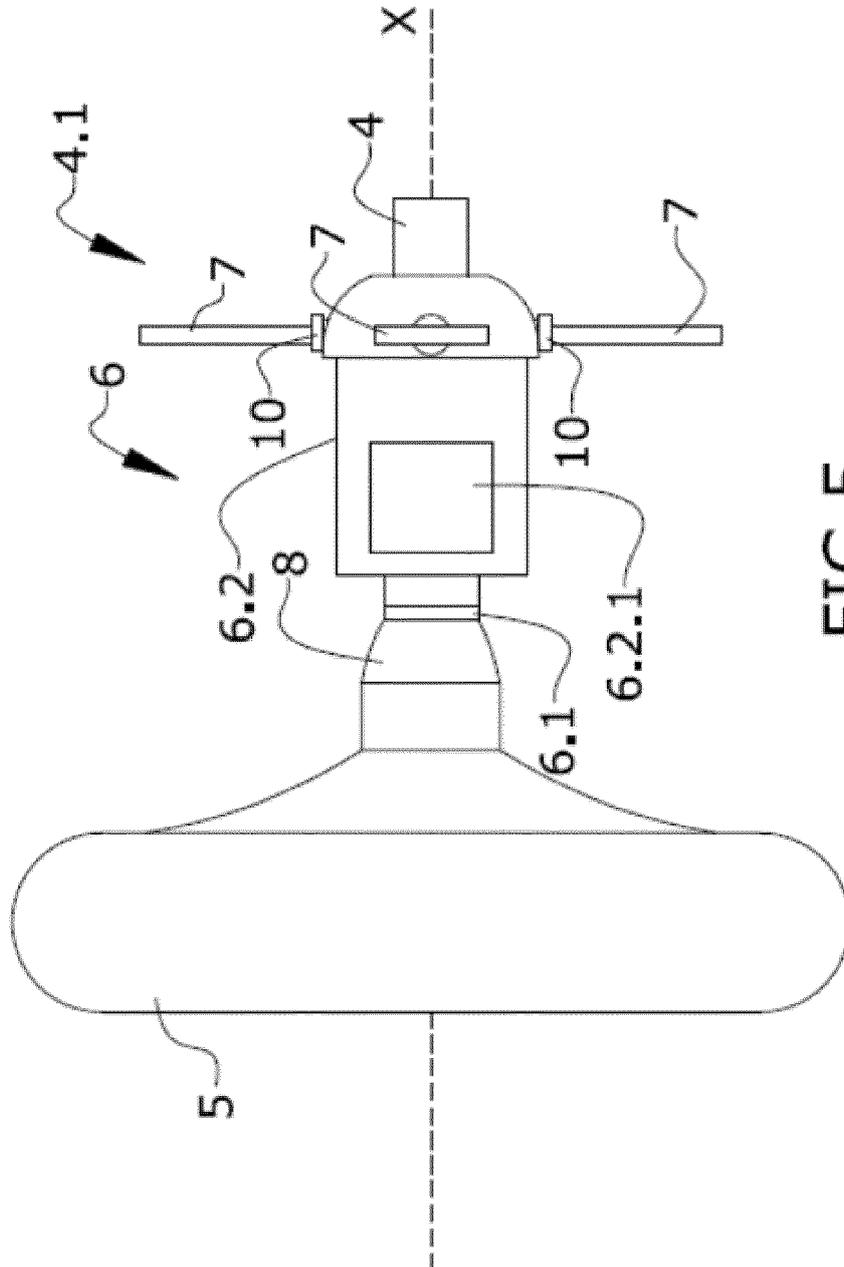


FIG. 5

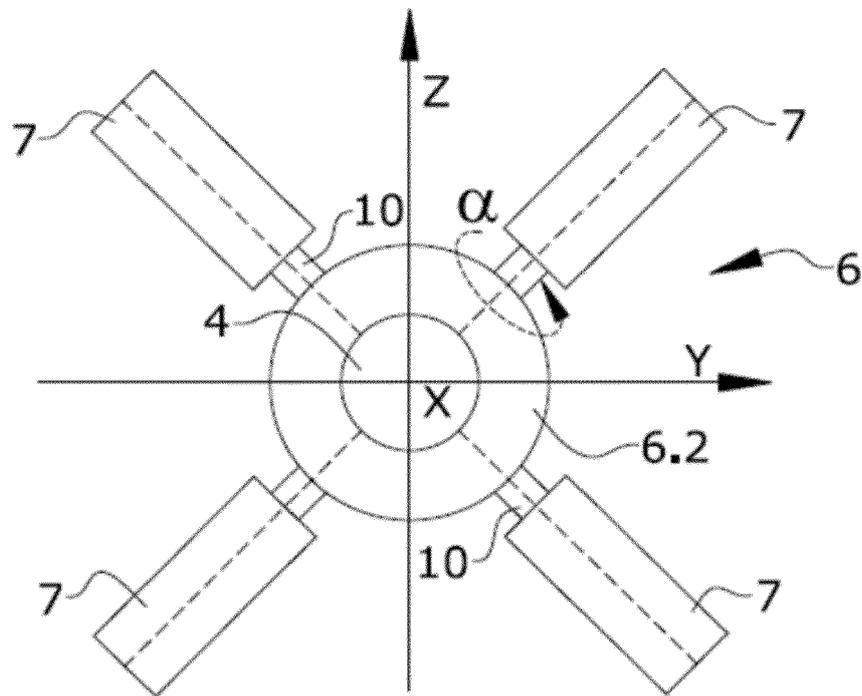


FIG. 6

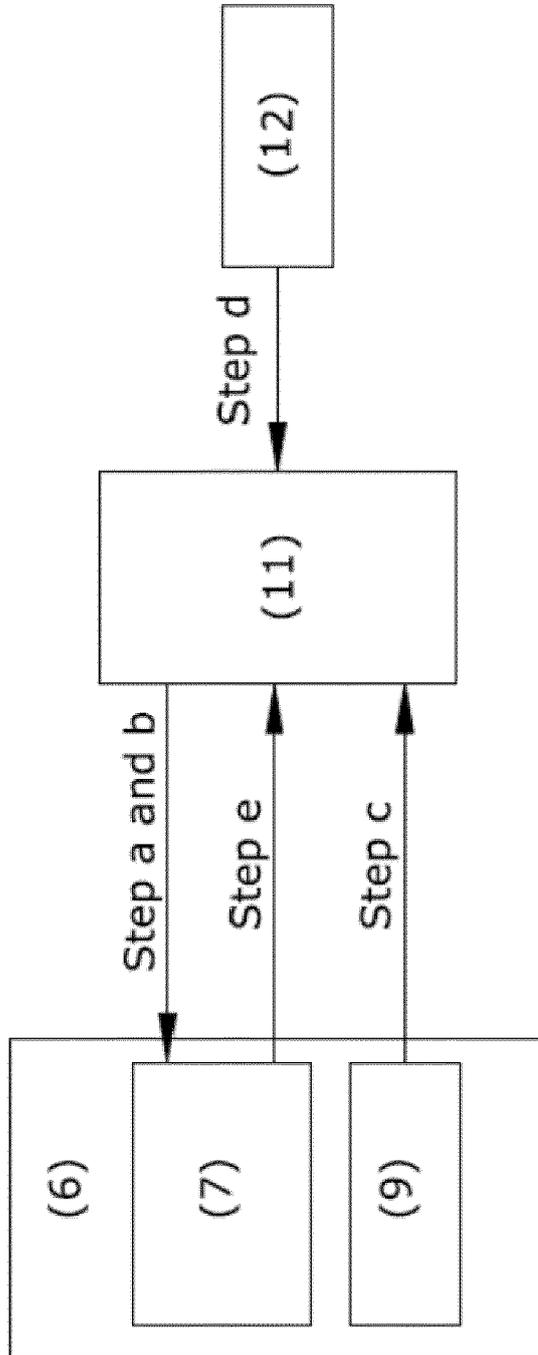


FIG.7



EUROPEAN SEARCH REPORT

Application Number
EP 20 38 2943

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DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
A	US 2014/306063 A1 (KUSNITZ JOSHUA M [US]) 16 October 2014 (2014-10-16) * the whole document * -----	1-15	INV. B64D39/00
A	EP 2 266 879 A1 (SELEX GALILEO SPA [IT]) 29 December 2010 (2010-12-29) * the whole document * -----	1-15	
A	US 2013/168497 A1 (RIX OHAD [IL]) 4 July 2013 (2013-07-04) * the whole document * -----	1-15	
A	US 2007/084968 A1 (THAL GERMAN V [US] ET AL) 19 April 2007 (2007-04-19) * the whole document * -----	1-15	
The present search report has been drawn up for all claims			TECHNICAL FIELDS SEARCHED (IPC)
			B64D B64C
Place of search		Date of completion of the search	Examiner
Munich		18 March 2021	Rusanu, Irina
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X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document			

EPO FORM 1503 03.82 (P04C01)

ANNEX TO THE EUROPEAN SEARCH REPORT
ON EUROPEAN PATENT APPLICATION NO.

EP 20 38 2943

5 This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report.
The members are as contained in the European Patent Office EDP file on
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18-03-2021

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 2014306063 A1	16-10-2014	US 2014306063 A1 WO 2014204539 A1	16-10-2014 24-12-2014
EP 2266879 A1	29-12-2010	CA 2706278 A1 EP 2266879 A1 ES 2437673 T3 IT 1394808 B1 RU 2010122757 A US 2011001011 A1	04-12-2010 29-12-2010 13-01-2014 13-07-2012 10-12-2011 06-01-2011
US 2013168497 A1	04-07-2013	EP 2800695 A2 EP 2800696 A2 IL 233472 A IL 233474 A KR 20140114003 A KR 20140114004 A SG 10201605471V A SG 10201605480Y A SG 11201403783R A SG 11201403787X A US 2013168497 A1 US 2013168498 A1 US 2014353430 A1 US 2015136911 A1 US 2016039531 A1 US 2017166319 A1 US 2017297735 A1 US 2019359345 A1 US 2019382126 A1 WO 2013102903 A2 WO 2013102906 A2	12-11-2014 12-11-2014 31-07-2018 28-02-2018 25-09-2014 25-09-2014 30-08-2016 30-08-2016 28-08-2014 28-08-2014 04-07-2013 04-07-2013 04-12-2014 21-05-2015 11-02-2016 15-06-2017 19-10-2017 28-11-2019 19-12-2019 11-07-2013 11-07-2013
US 2007084968 A1	19-04-2007	AT 423062 T EP 1784332 A1 ES 2321431 T3 US 2007084968 A1 WO 2006085986 A1	15-03-2009 16-05-2007 05-06-2009 19-04-2007 17-08-2006